

Handbook of Polymeric Foams and Foam Technology

edited by
Daniel Klempner and Kurt C. Frisch

with 179 Figures and 79 Tables



Hanser Publishers, Munich Vienna New York Barcelona

Distributed in the United States of America and in Canada by
Oxford University Press New York

The editors

Dr. Daniel Klempner and Dr. Kurt C. Frisch, both University of Detroit, Polymer Institute, Detroit, USA

Distributed in USA and in Canada by
Oxford University Press
200 Madison Avenue, New York, N.Y. 10016

Distributed in all other countries by
Carl Hanser Verlag
Kolbergerstr. 22
D-8000 München 80

The use of general descriptive names, trademarks, etc., in this publication, even if the former are not especially identified, is not to be taken as a sign that such names, as understood by the Trade Marks and Merchandise Marks Act, may accordingly be used freely by anyone.

While the advice and information in this book are believed to be true and accurate at the date of going to press, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Die Deutsche Bibliothek – CIP-Einheitsaufnahme

Handbook of polymeric foams and foam technology / ed. by
Daniel Klempner and Kurt C. Frisch. – Munich ; Vienna ; New
York ; Barcelona : Hanser, 1991
ISBN 3-446-15097-8
NE: Klempner, Daniel [Hrsg.]

ISBN 3-446-15097-8 Carl Hanser Verlag, Munich Vienna New York Barcelona
ISBN 0-19-520929-X
Library of Congress Catalog Card Number 91-058240

All rights reserved. No part of this book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying or by any information storage and retrieval system, without permission from the publisher (except Chap. 6B for the purpose of official use by Morrison Molded Fiber Glas Company).

Copyright © Carl Hanser Verlag, Munich Vienna New York Barcelona, 1991
Printed in Germany by Passavia Druckerei GmbH Passau

.....	333
.....	334
.....	337
.....	338
.....	339
.....	339
.....	341
.....	345
.....	349
.....	352
.....	353
.....	355
.....	356
.....	356
.....	359
.....	364
.....	368
.....	372
.....	374
.....	375
.....	276
.....	376
.....	378
.....	402
.....	407
.....	407
.....	408
.....	409
.....	411
.....	413

Chapter 1

INTRODUCTION

by Dr. K. C. Frisch and Dr. D. Klempner

Polymer Technologies, Inc. University of Detroit, Detroit, Michigan 48221

Cellular plastics or plastic foams, also referred to as expanded or sponge plastics, generally consist of a minimum of two phases, a solid polymer matrix and a gaseous phase derived from a blowing agent. There may be more than one solid phase present, as in the case of a blend or alloy of polymers (generally heterogeneous).

Other solid phases may be present in the foams in the form of fillers, either fibrous or other shapes. The fillers may be of inorganic origin, of a material such as glass, ceramic, or metal, or polymeric in nature. Foams may be flexible or rigid, depending upon whether their glass transition temperature is below or above room temperature, which in turn depends upon their chemical composition, the degree of crystallinity, and the degree of cross-linking. Intermediate between flexible and rigid foams are semirigid or semiflexible foams. The cell geometry may be open-(tunnels between the cells), or closed-cell. Closed-cell foams are most suitable for thermal insulation and are generally rigid, while open-celled foams are best for car seating, furniture, bedding and acoustical insulation, among other uses, and are generally flexible.

Plastic foams can be produced in a great variety of densities ranging from about 1.6 kg/m^3 (0.1 lb/ft^3) to over 960 kg/m^3 (60 lb/ft^3) [1]. Since the mechanical strength properties are generally proportional to the foam densities, the applications of these foams usually determine which range of foam densities should be produced. Thus, rigid foams for load-bearing applications require high density, fiber reinforcement, or both, while low densities are usually used for thermal insulation. Low-density flexible foams (around 30 kg/m^3) are usually used in furniture and automotive seating, while somewhat higher densities are used for carpet backing and energy-absorbing applications.

The foaming of polymeric materials can be carried out by either mechanical, chemical, or physical means. Some of the most commonly used methods are the following [2].

1. Thermal decomposition of chemical blowing agents, generating either nitrogen or carbon dioxide or both, by application of heat or as a result of the exothermic heat of reaction during polymerization.
2. Mechanical whipping of gases (frothing) into a polymer system (melt, solution, or suspension), which hardens either by catalytic action or heat or both, thus entrapping the gas bubbles in the matrix.
3. Volatilization of low-boiling liquids (such as fluorocarbons or methylene chloride) within the polymer mass as a result of the exothermic heat of reaction or by application of heat.
4. Volatilization by the exothermic heat of reaction of gases produced during polymerization, such as occurs in the reaction of isocyanate with water to form carbon dioxide.
5. Expansion of gas dissolved in a polymer mass upon reduction of pressure in the system.
6. Incorporation of microspheres into a polymer mass. The hollow microspheres may consist of either glass or plastic beads.

7. Expansion of gas-filled beads by application of heat, or expansion of these beads in a polymer mass by heat of reaction (*e.g.*, expansion of polystyrene beads in a polyurethane or epoxy resin system).

Most of these methods of foaming are discussed in detail in Chapter 17.

The production of foams can take place by many different techniques. These include [3]:

1. Production of continuous slab stock by pouring; multi-component foam machines employing impingement mixing are used.
2. Compression molding of foams.
3. Reaction injection molding, usually by impingement mixing.
4. Foaming in place, by pouring from a dual or multi-component head.
5. Spraying of foams.
6. Extrusion of foams using expandable beads or pellets.
7. Injection molding of expandable beads or pellets.
8. Rotational casting of foams.
9. Frothing of foams by introduction either of air or of a low-boiling volatile solvent (such as dichlorodifluoromethane, CFC 12).
10. Lamination of foams (foam board production).
11. Production of foam composites.
12. Precipitation foam processes, in which a polymer phase is formed by polymerization or precipitation from a liquid that is later allowed to escape.

Further details concerning the fundamentals of foam formation are discussed in Chapter 2, and particular techniques are covered in subsequent chapters in which they are applicable.

The markets for foams have been growing worldwide, with North America, the E.E.C., and Japan as the leading producers and consumers of foams. However, the Comecon countries, Latin America, especially Brazil, Argentina, and Mexico, and the Asian countries (other than Japan), such as Taiwan, South Korea, and India, are developing foam markets and production facilities rapidly. Many developing countries on all continents are using foams at an ever-increasing rate by starting foam production, employing either imported or locally produced raw materials, with major efforts being expended in utilizing certain domestic plant or forest products, especially for foam composites.

The major industries that use flexible or semiflexible foams are

Furniture
Transportation
Bedding
Carpet underlay
Packaging
Textile
Toys and novelties
Gasketing
Sports applications
Shock (vibration) and sound attenuation
Shoes

Markets for rigid foam include the following industries:

Building and construction
Appliances